SETI Institute

Radar and Near-Earth Asteroid Exploration Missions

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SSERVI Exploration Science Forum

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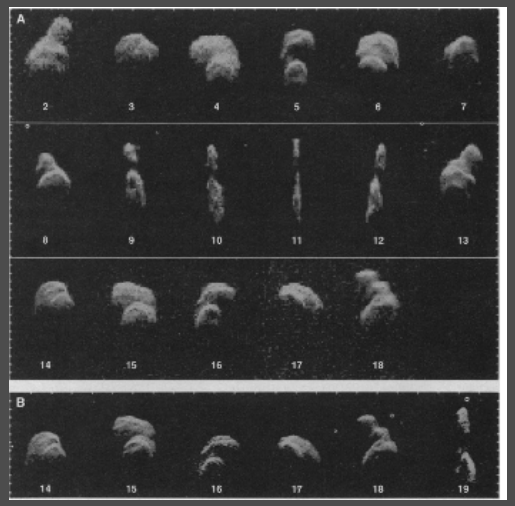
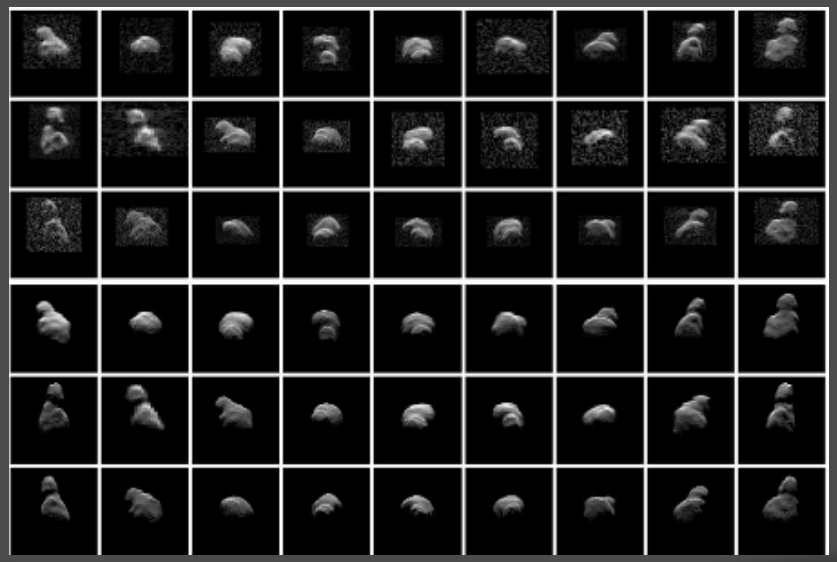
Case Study #1: Toutatis

Toutatis in 1992-1996

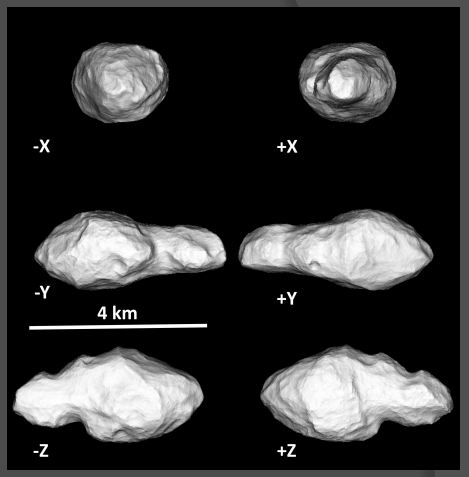
Work led by Steve Ostro and Scott Hudson



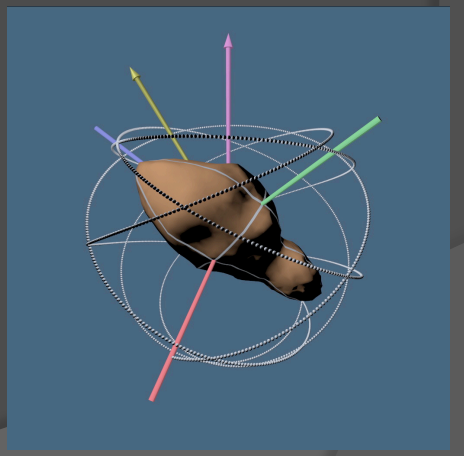
1992 Arecibo & Goldstone Radar Images



1996 Arecibo & Goldstone Radar Images

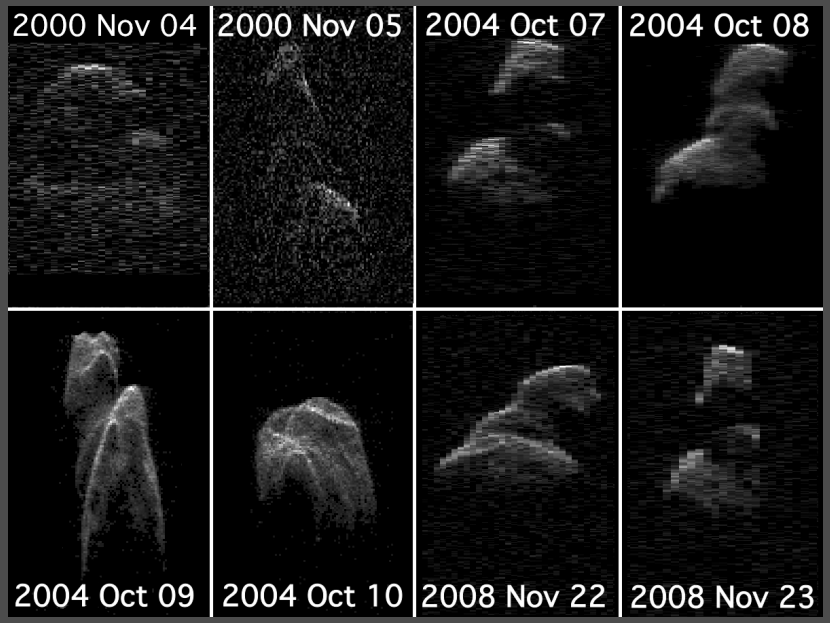


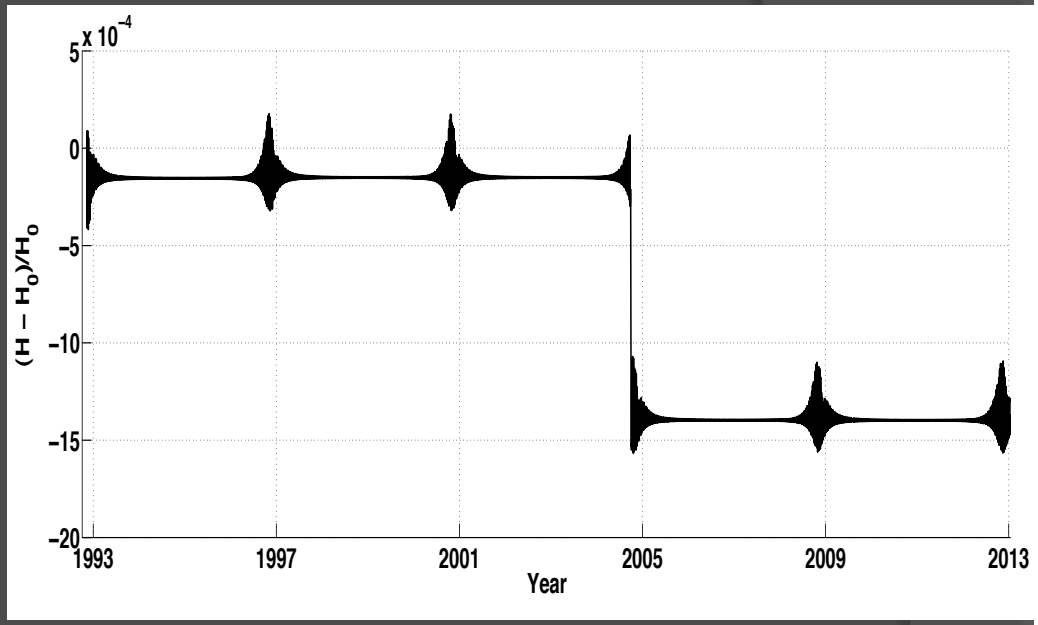
Old Radar-derived shape of Toutatis.



Toutatis' NPA Spin State

Toutatis in 2000-2008





Changes in Toutatis' angular momentum from Dec 1992 to Dec 2012. Chart and fit from Takahashi, Busch, & Scheeres 2013.

- Radar images: Goldstone '00, Arecibo '04 & '08.
- Mismatch between '92-'96 spin state fit and later images.
- Toutatis is torqued by gravitational tides from other objects. The largest spin state change since 1992 was during the '04 flyby.

Spin State Model

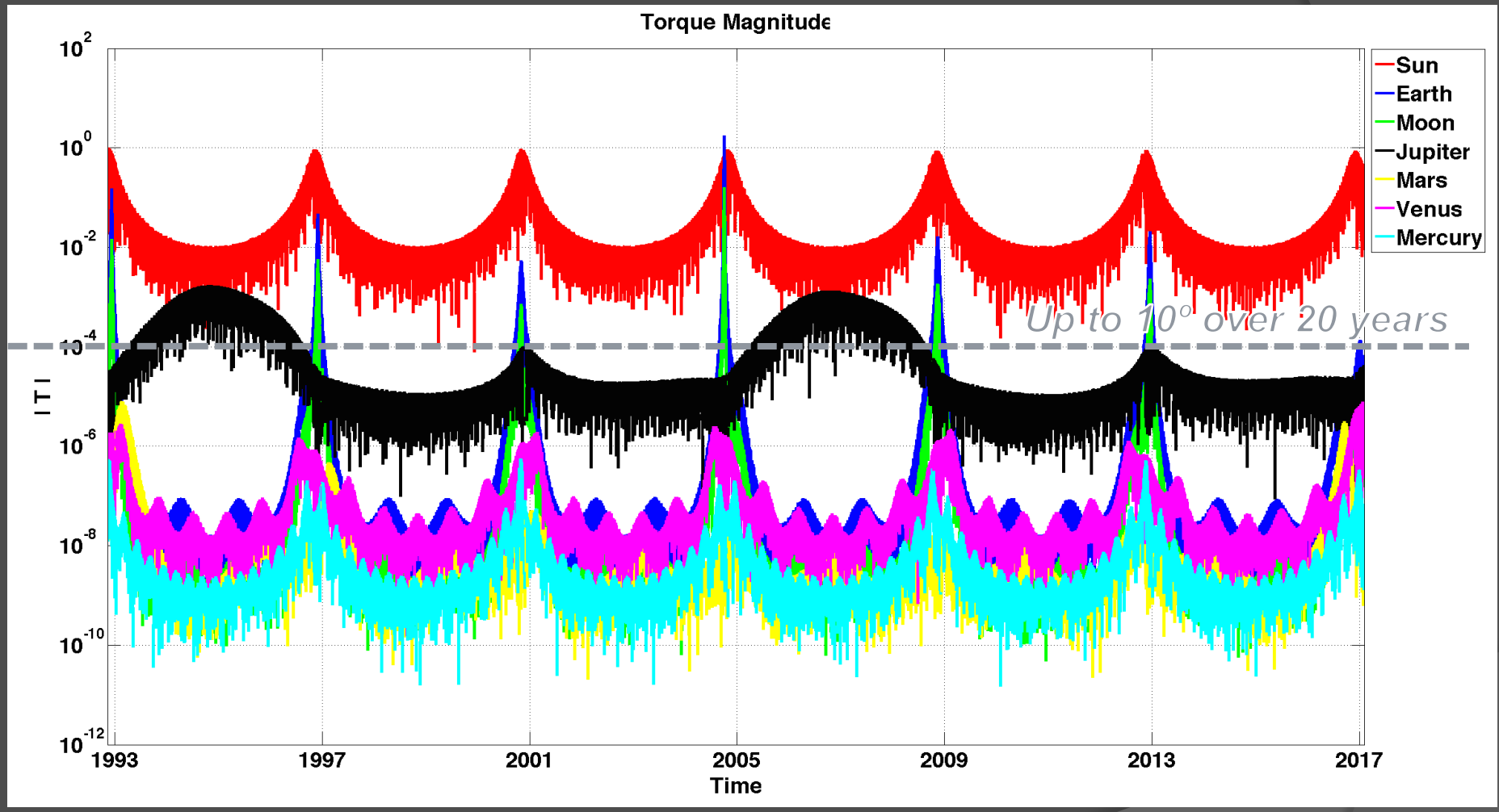
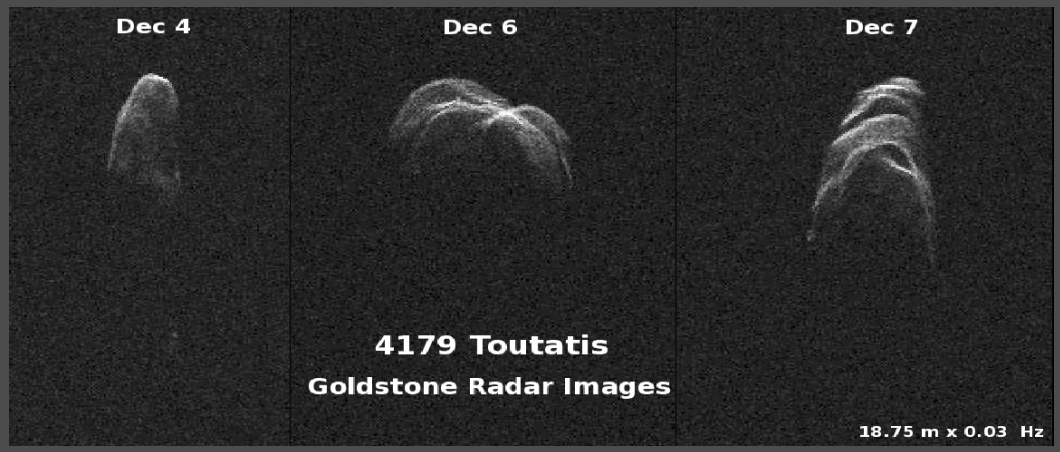
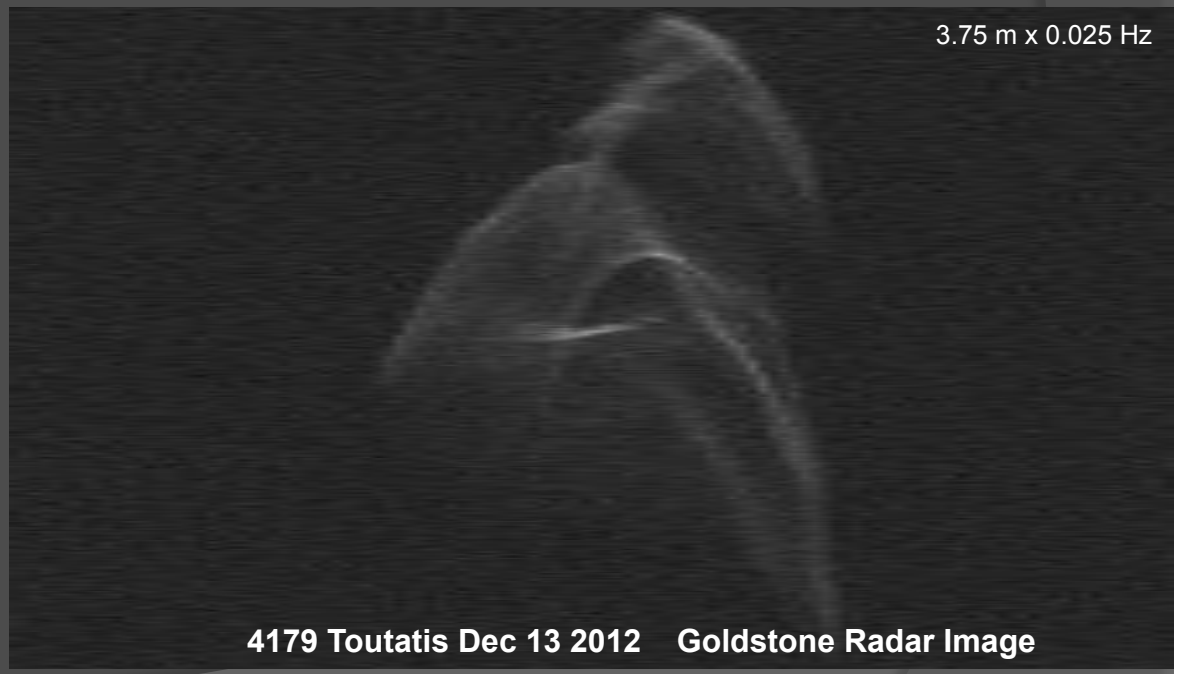


Chart by Yu Takahashi

- Takahashi, Busch, Scheeres (2013) included torques from Earth and Sun. *No longer good enough.* Now adding Moon and Jupiter.

Toutatis in 2012





Images by M. Brozovic

Toutatis Seen By Radar and Spacecraft

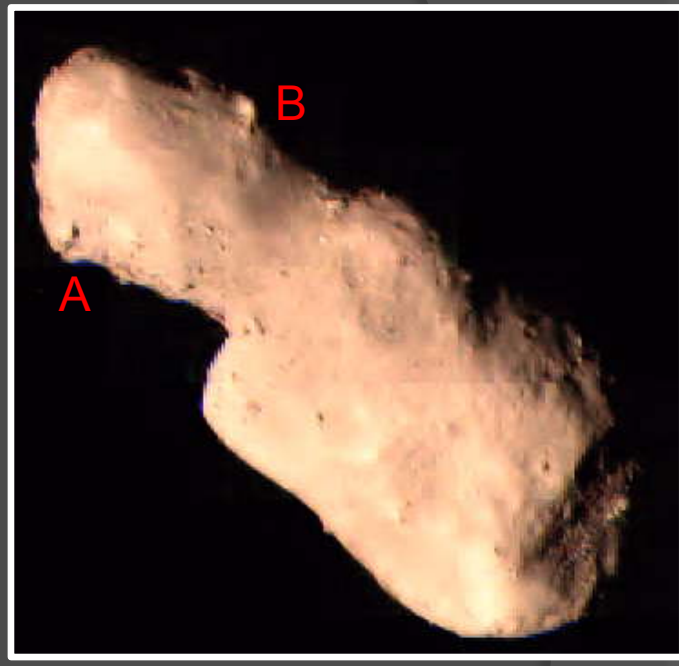


Image from Chang'e 2 *(Huang et al. 2013)*

- Radar-derived spin state model is quite good.
- Old radar shape model limited by viewing geometry and fitting procedure.
- Radar and spacecraft see many of the same surface features.

- Radar astrometry on Toutatis gave the asteroid's position to ±600 m (3σ).

Case Study #2: 2008 EV5

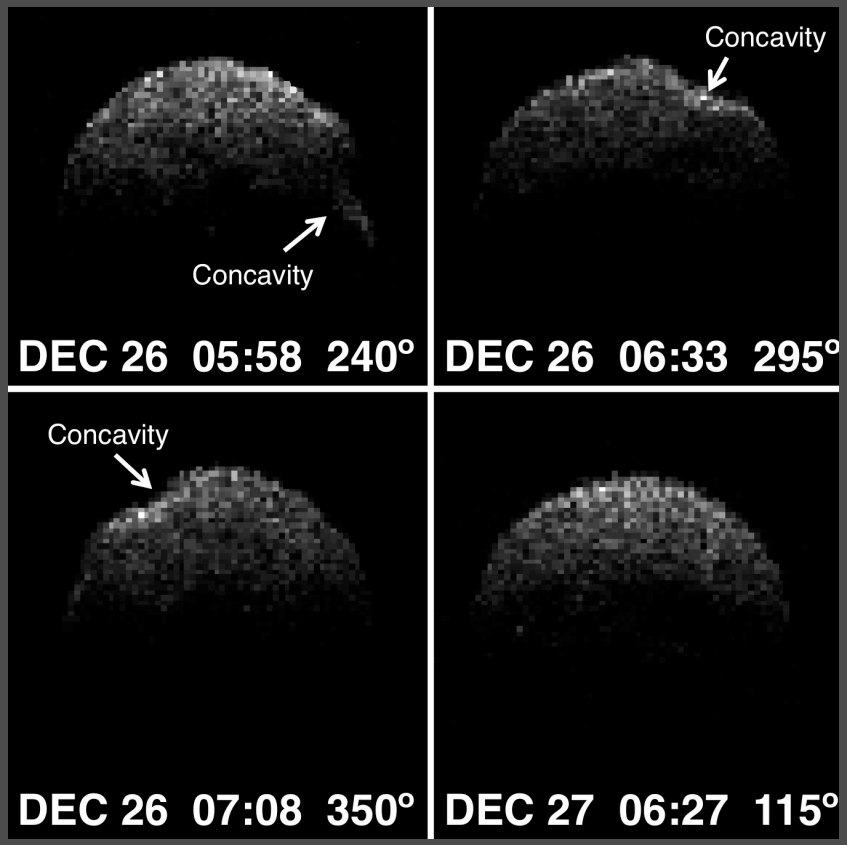
2008 Radar Campaign

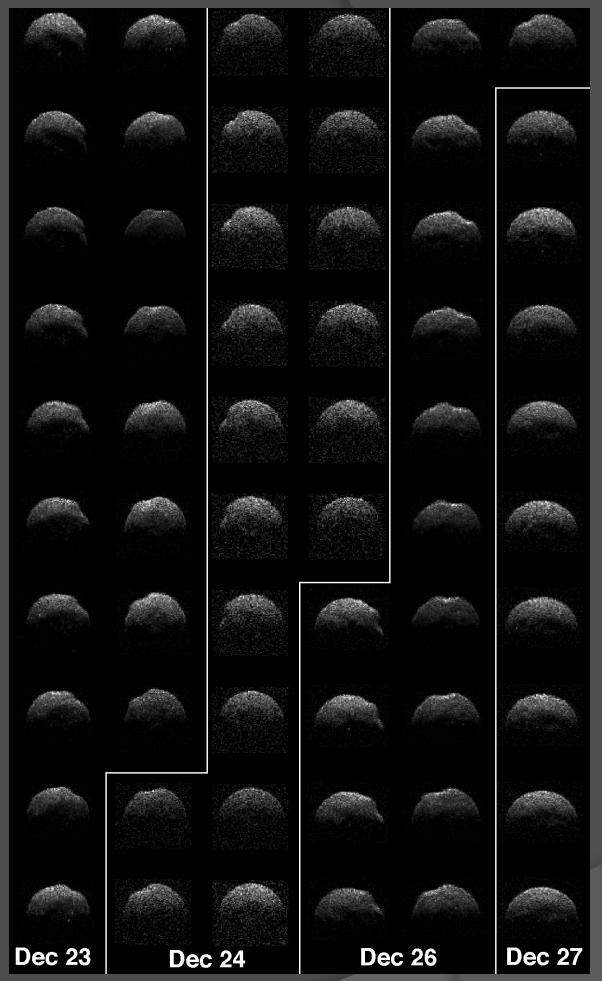
Arecibo

Goldstone 70-m

Green Bank

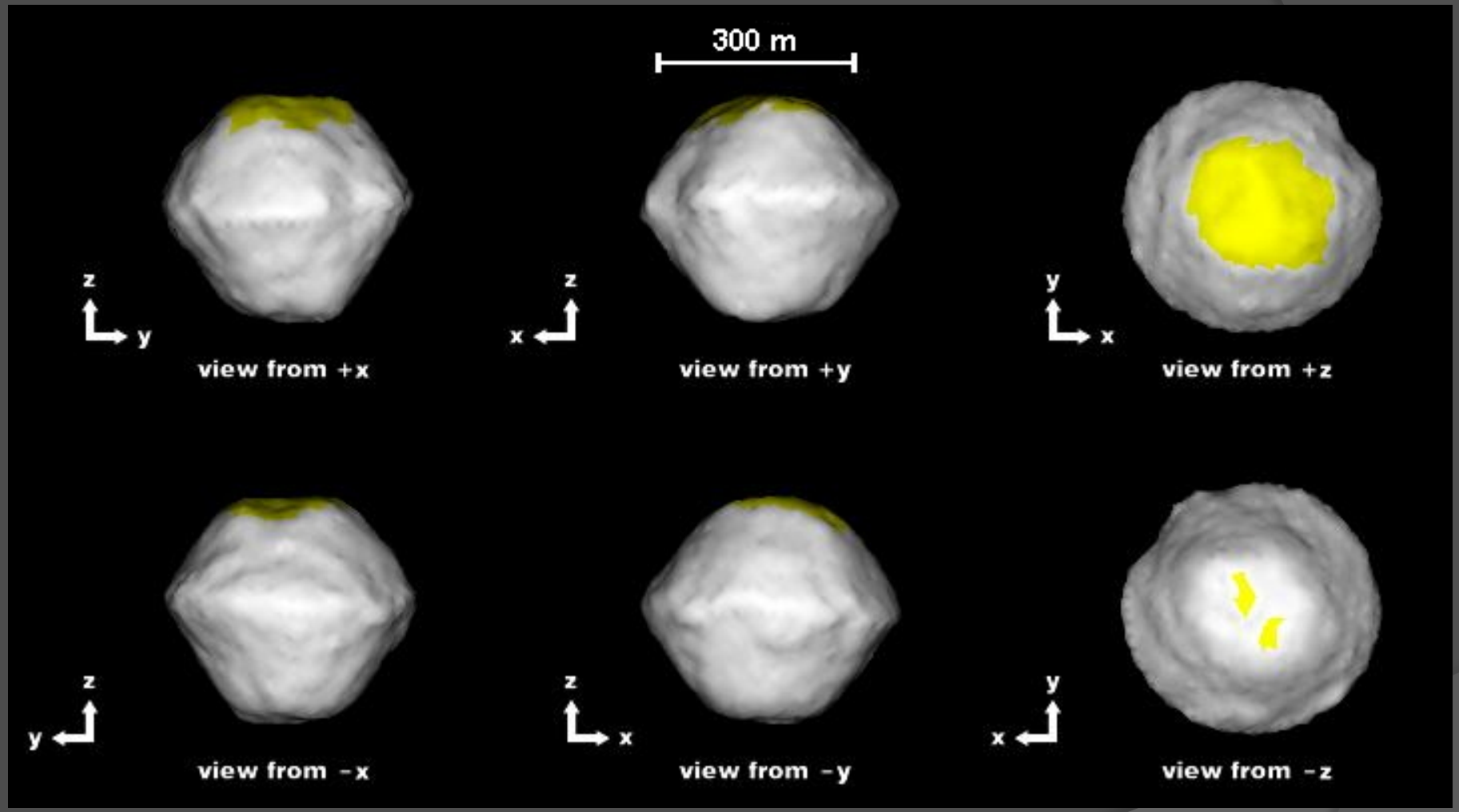
Very Long Baseline Array



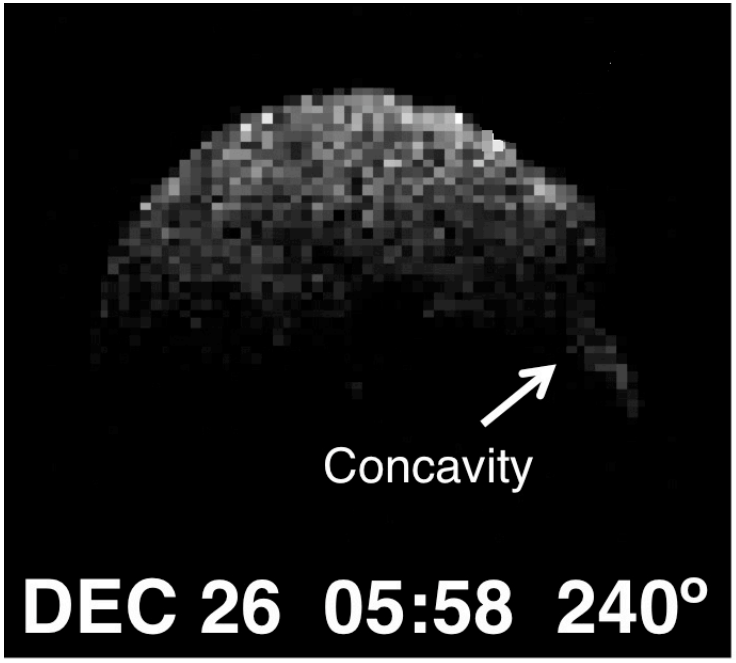


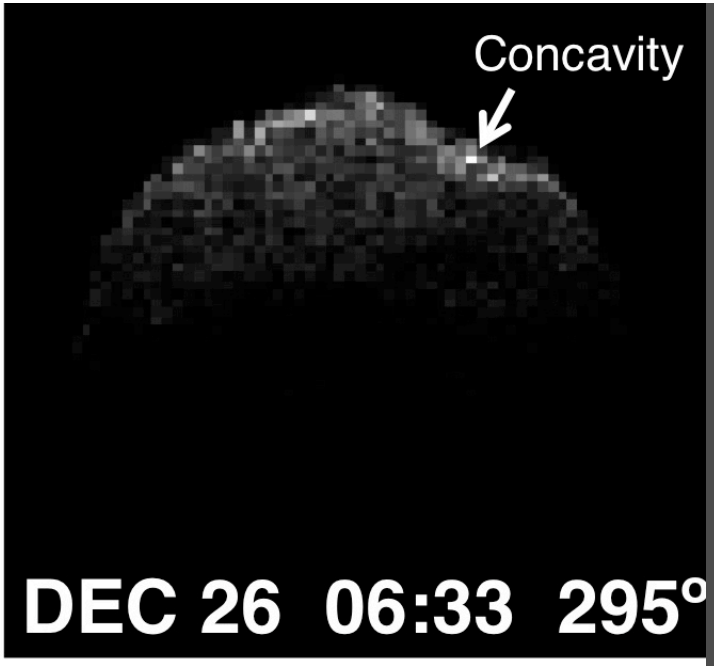
Arecibo delay-Dopper images of EV5; 7.5 m/pixel range resolution

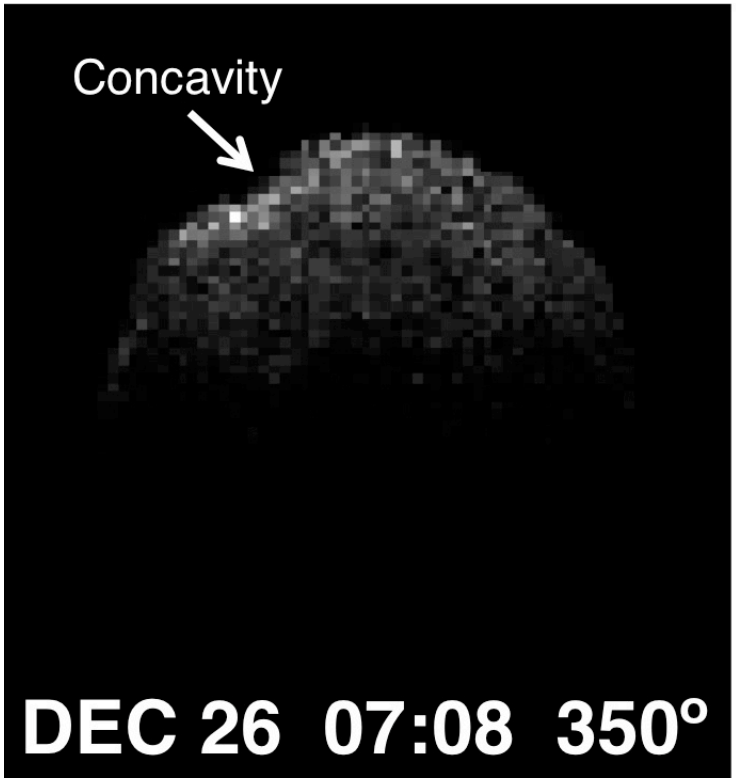
EV5's Size And Shape



- Best-Fit Shape: ~400 m spheroid. The ridge is on the equator, and the concavity breaks the ridgeline.
  - *Caveat: The poles, particular the north pole, were not seen or were seen only at grazing incidence.*



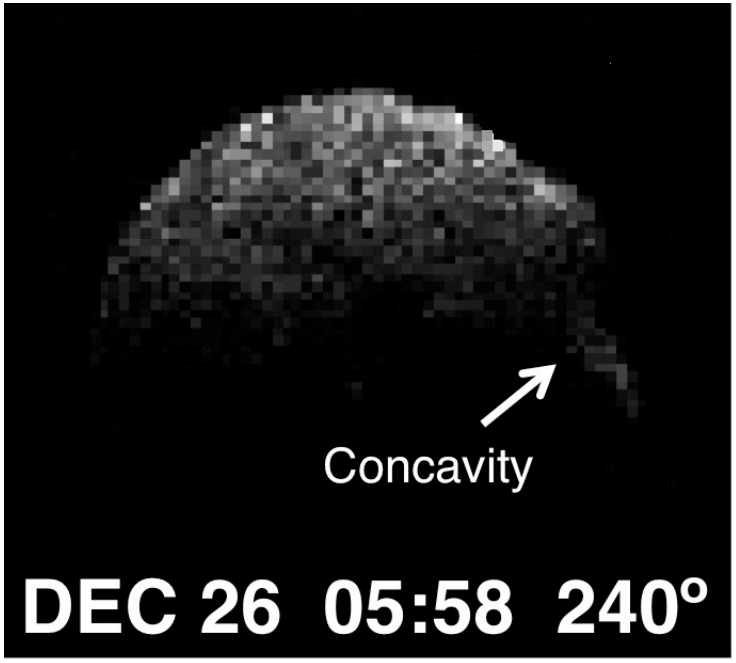


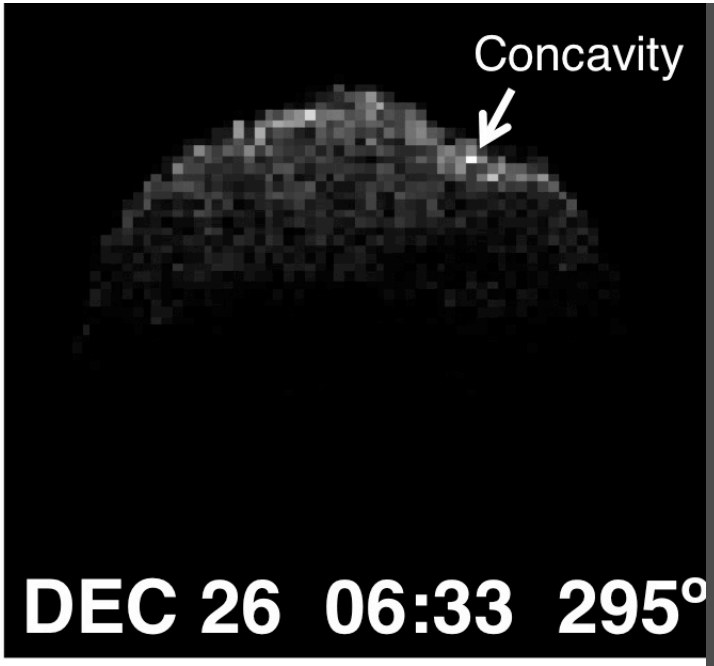


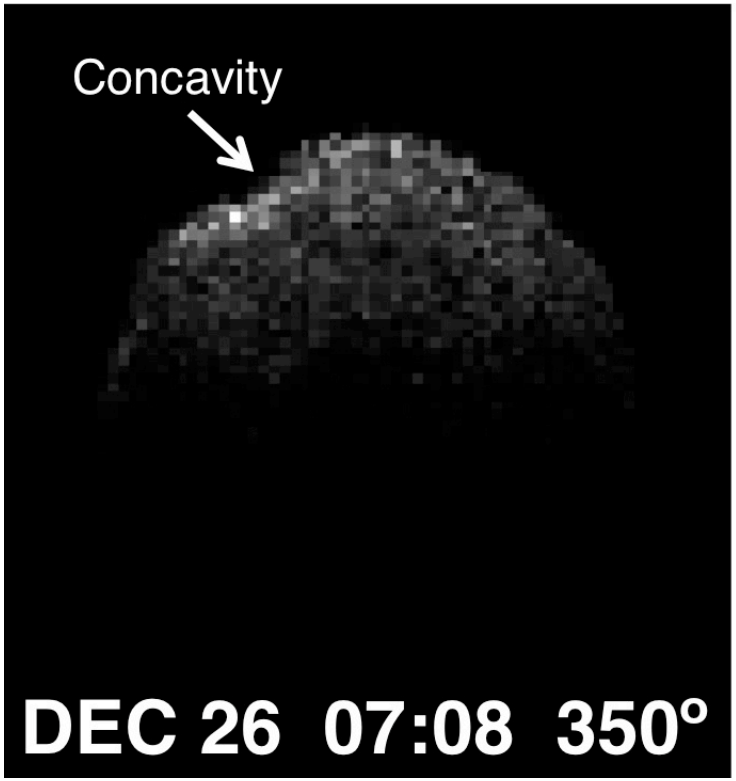
2008 EV5

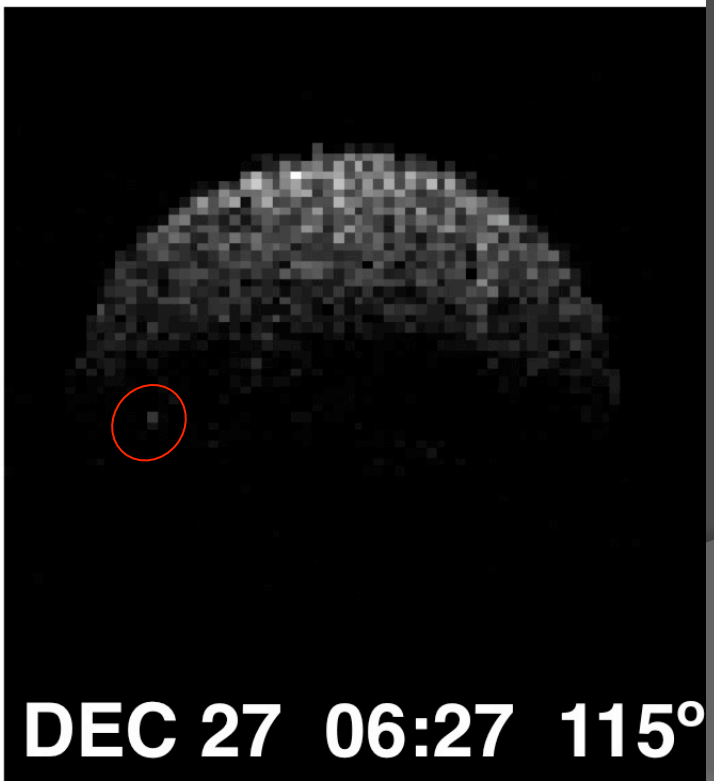
Arecibo images; 2008 December. Resolution 7.5 m in range; again the asteroid is ~400 m in diameter.

Note the bright pixels visible on the limb, particularly on December 27.









2008 EV5

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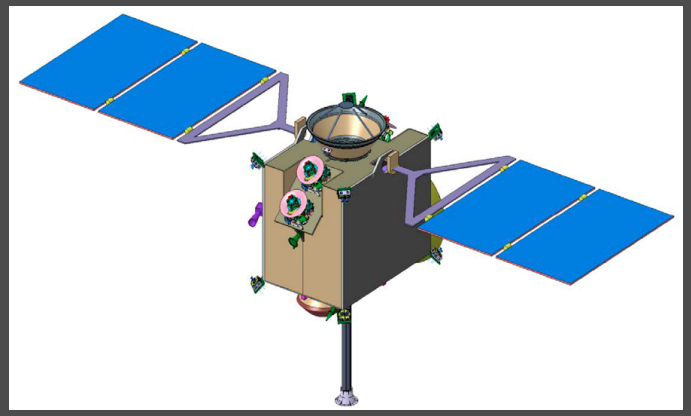
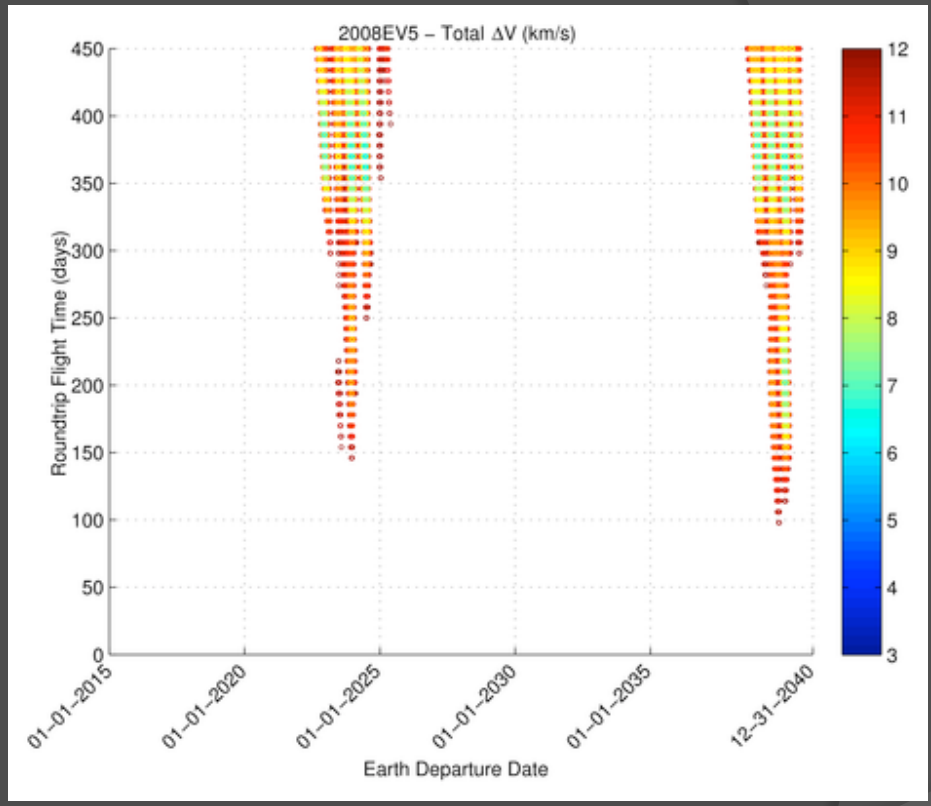
Proposed Missions to EV5 - I



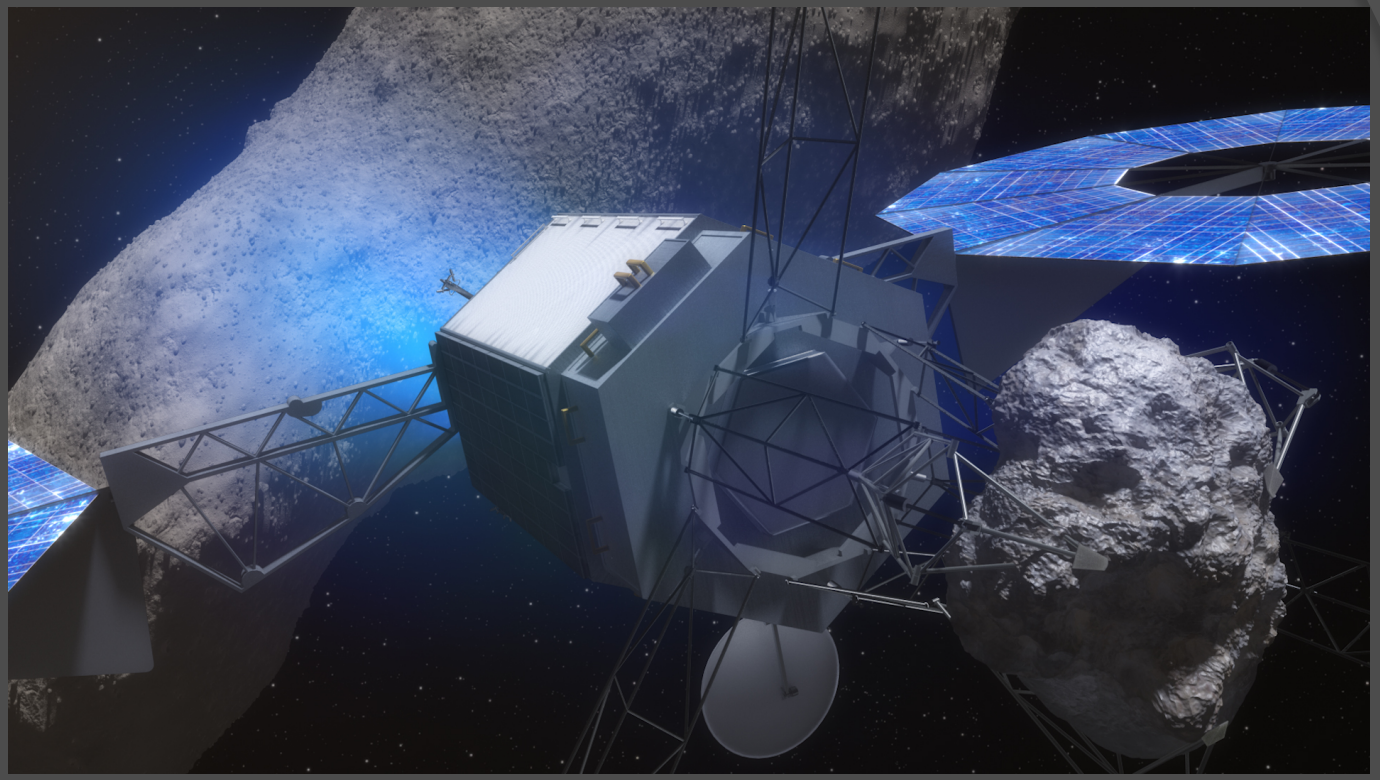
Marco Polo R. Proposed launch 2022-2024. In February 2014, ESA elected to not pursue the mission



NHATS. Human mission trajectories to EV5 in 2024 and 2039. 6.25 – 7 km/s Δv from LEO, ~1 year round-trip.

May be excluded as human NEO mission target due to long mission duration.

Proposed Missions to EV5 - II



ARM / ARRM Pick-up-a-rock. Would return 30-45 t boulder from EV5 to Earth-Moon space.
Launch c. 2019-2022; return c. 2025-2027.

NASA decision pending